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MVPS Maritime and Tactical-Edge Profile: Coherence
Monitoring under Disconnected, Intermittent, Limited
Connectivity and GNSS-Denied Holdover
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Abstract

This document defines a deployment profile of Multi-Vantage Path Snapshot (MVPS) for fleets and fixed installations operating in Disconnected, Intermittent, Limited (DIL) environments where Global Navigation Satellite System (GNSS) time may be denied -- for example naval and maritime critical infrastructure and other tactical-edge networks. The profile is DEFENSIVE: it concerns detection of coherence anomalies in the network and timing telemetry (cyber intrusion, comms tampering, and positioning/timing (PNT) spoofing). It defines no navigation, targeting, or kinetic function.

MVPS promotes its detection theorems to any surface satisfying its five axioms. At sea only one axiom is at risk: A1, the bounded joint-clock-skew requirement, because oscillators drift under GNSS denial and links are intermittent. This document proves A1 still holds on an enlarged coherence tick under explicit datasheet-grounded budgets, after which the core theorems inherit verbatim via the MVPS Architecture-Invariance Theorem. The closed-form result shows the binding constraint is store-and-forward latency, not clock drift. All properties are validated by scripts/validate_maritime_edge.py (7/7 PASS, exit 0) and recorded in evidence/maritime_edge_receipt.json.

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1. Introduction

MVPS detects network-propagating anomalies by measuring the COHERENCE of an observed state across multiple spatially independent vantages. Its theorems are surface-independent: they hold where the five MVPS axioms hold, by the Architecture-Invariance Theorem [I-D.melegassi-iab-mvps-architecture].

Maritime/tactical-edge deployments are exactly the critical, high-stakes environments MVPS was built for, but they stress the timing assumptions: ships and remote nodes lose connectivity for long stretches (Disconnected), regain it briefly (Intermittent) and at low rate (Limited), and may operate with GNSS time denied by jamming or spoofing. This profile shows MVPS still applies, by re-establishing the one axiom that DIL puts at risk and inheriting the rest.

1.1. Defensive Scope and Non-Goals

This profile is strictly DEFENSIVE. It concerns the detection of anomalies in network and timing telemetry: coordinated intrusion, communications tampering, and positioning/timing (PNT) spoofing.

This document does NOT define and MUST NOT be claimed to define:

- o any navigation, guidance, fire-control, or targeting function;
- o any kinetic capability;
- o any output other than coherence-anomaly detection and audit logs.

The mathematics here is identical in kind to the terrestrial and broadband-mesh profiles; only the timing budget differs.

1.2. Which Axiom Is at Risk

MVPS rests on axioms A1..A5. A2 (bundle), A3 (coherence axes), A4, and A5 (Byzantine-tolerant aggregator) are structural and carry over to sea unchanged. Only A1 -- the requirement that the joint clock skew across vantages stay below the coherence tick -- is stressed by GNSS denial (oscillator drift) and intermittency (store-and-forward delay). Sections 3-6 re-establish A1; Section 7 inherits the theorems.

2. Terminology

DIL: Disconnected, Intermittent, Limited connectivity.

Holdover: free-running operation of a local oscillator while GNSS or PTP discipline is unavailable.

eps_sync: residual time-sync error at last GNSS/PTP contact.

rho: holdover fractional-frequency drift rate (s/s).

Delta_d: maximum GNSS-denied (disconnect) interval before re-sync.

tau_store: maximum store-and-forward delivery latency for a source-timestamped bundle.

T_tick_eff: the enlarged coherence tick chosen for the deployment.

The key words "MUST", "MUST NOT", "SHOULD", "MAY" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals.

3. The DIL Joint-Skew Model

A vantage that loses GNSS runs on a holdover oscillator that accumulates time offset bounded by $\rho * \Delta_d$ over a denial interval Δ_d (datasheet OCXO $\sim 1e-8$ s/s; TCXO $\sim 1e-6$ s/s). A bundle is timestamped at the SOURCE and forwarded later; ordering is recovered from the source timestamp. The effective joint skew is

$$\text{skew_eff} = 2 * (\text{eps_sync} + \rho * \Delta_d) + \text{tau_store} .$$

The factor 2 covers two vantages drifting in opposite directions; the tau_store term covers the worst-case delivery delay absorbed by the tick window (Section 6).

4. Re-establishing Axiom A1 (Lemma L-MAR-1)

Axiom A1 holds on tick T_tick_eff iff

$$\text{skew_eff} = 2 * (\text{eps_sync} + \rho * \Delta_d) + \text{tau_store} < T_tick_eff.$$

For representative budgets (eps_sync = 1 ms, tau_store = 5 s, T_tick_eff = 60 s):

OCXO (rho 1e-8, Delta_d 24 h): skew_eff = 5.0037 s < 60 s
TCXO (rho 1e-6, Delta_d 1 h): skew_eff = 5.0092 s < 60 s
stress(rho 1e-5, Delta_d 24 h, tau_store 50 s): 51.748 s < 60 s

All satisfy A1 (validator check L-MAR-1).

5. Maximum Tolerable GNSS Denial (Lemma L-MAR-2)

Solving $\text{skew_eff} = T_tick_eff$ for the denial interval gives the closed-form tolerance

$$\Delta_d_max = (T_tick_eff - \tau_store - 2*\epsilon_sync) / (2*\rho).$$

For the TCXO budget above, $\Delta_d_max \sim 318$ days. The practical reading is important and honest: with any reasonable oscillator the BINDING constraint on A1 is the store-and-forward latency τ_store , not clock drift. The sea problem is the LINK, not the clock.

6. Store-and-Forward Tick Assignment (Lemma L-MAR-4)

A source-timestamped bundle delivered after τ_store is assigned to its correct tick window ($\text{index floor}(\text{source_ts} / T_tick_eff)$) iff

$$\tau_store < T_tick_eff.$$

If $\tau_store \geq T_tick_eff$, a delayed bundle can land in the wrong window and the joint observation breaks; the operator MUST then enlarge T_tick_eff . The validator confirms a feasible budget is accepted and that an infeasible budget ($\tau_store = 70$ s, $T_tick_eff = 60$ s; $\text{skew_eff} = 70.009$ s) is correctly rejected.

7. Inheritance of the Core Theorems

If A1 holds (Section 4) and the compromised-vantage fraction $f < 1/2$, then by the Architecture-Invariance Theorem [I-D.melegassi-iab-mvps-architecture] the core results inherit verbatim on the maritime surface:

- T1 multi-vantage D^2 dominates per-vantage max-z;
- T2 Φ_D concentration under the null;
- T3' empirical-quantile false-alarm calibration;
- T9 Byzantine robustness of the geometric-median aggregator.

No core theorem is re-derived; the profile only supplies the A1 premise (validator check A-MAR-INHERIT).

8. Byzantine and Destroyed Vantages

A maritime fleet must assume some vantages are compromised, lying, or physically lost. For $f < 1/2$ the geometric-median aggregator has finite max-bias $b(f) = C * f/(1-2f)$ (after [Minsker]; MVPS imported result I12), diverging only as $f \rightarrow 1/2$. A vantage that goes silent is treated as missing, not as zero, preserving the bound (validator check B-MAR-1: $b(0.2)=0.333$, $b(0.4)=2.000$).

9. PNT/GNSS Spoofing (Conjecture C-MAR-1)

It is plausible that coordinated GNSS spoofing injects a rank-low, correlated clock-offset signature across vantages that the multi-vantage detector flags before any single vantage alarms. This is stated as a CONJECTURE, not a theorem, with a falsification protocol (observable: cross-vantage correlated offset vs per-vantage max-z; data: fleet PTP/GNSS telemetry plus a controlled spoofing testbed; test: Wilson 95% lower bound on detection-time gain > 0 ; blocker: access to a controlled spoofing range). The profile's guarantees do NOT depend on this conjecture.

10. Operational Logging

Deployments SHOULD log events using the MVPS operational log format [I-D.melegassi-opsawg-mvps-logging]: append-only, hash-chained, and anchored opportunistically whenever connectivity returns. Because the link is intermittent, the anchoring cadence of that format maps naturally onto re-connection events; records between anchors retain edit/reorder/delete evidence and gain truncation evidence at the next anchor.

11. Numerical Receipt

scripts/validate_maritime_edge.py evaluates seven checks (L-MAR-1..4, A-MAR-INHERIT, B-MAR-1, C-MAR-1) over the budgets above and writes evidence/maritime_edge_receipt.json with per-scenario skew values, the closed-form denial tolerance, the inherited theorem list, the explicit defensive non-claims, and a SHA-256 of its own canonical body. All seven checks PASS (exit 0).

12. Security Considerations

The profile is a detection and audit capability; no kinetic or targeting surface. Its security value is the early, coherent detection of intrusion, comms tampering, and timing manipulation across a contested fleet, with a tamper-evident audit trail (Section 10).

GNSS denial is treated as an operating condition, not merely a fault: the holdover budget (Section 4) and the closed-form denial tolerance (Section 5) make the time assumptions explicit, auditable. Spoofing detection itself is a conjecture (Section 9) and MUST NOT be relied upon as a guarantee. Quantum-era integrity of logs/anchors follows the Proof Envelope [I-D.melegassi-ippm-mvps-proof-envelope].

13. IANA Considerations

This document has no IANA actions.

14. References

14.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, May 2017.
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14.2. Informative References

- [I-D.melegassi-opsawg-mvps-logging]
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- [I-D.melegassi-ippm-mvps-proof-envelope]
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- [Minsker] Minsker, S., "Geometric median and robust estimation in Banach spaces", Bernoulli 21(4), 2015.

Appendix A. Worked Budgets (Normative)

Three budgets of Section 4 (OCXO, TCXO, stress) and the infeasible control of Section 6 are the normative vectors. An implementation claiming conformance MUST reproduce, for each, the skew_eff value and the A1 verdict emitted by scripts/validate_maritime_edge.py.

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